CSE410: Digital Signal Processing

Introduction
Part-1

Lesson Outline

- ❑Introduction
- ❑Signals
- ❑Systems
- ❑Signal processing
- ❑Filters

Introduction

The concepts of signals and systems arise in a wide variety of areas:

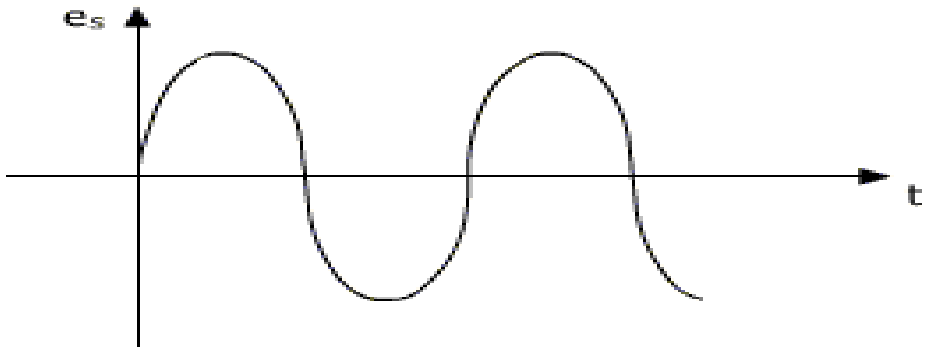
- Communications
- Circuit design
- Biomedical engineering
- Power systems
- Speech processing etc.

Signals

- Basically it is a physical quantity. It is described as a function with some independent or dependent variables.
- Signals can be One-dimensional or multidimensional.
  - One-dimensional signals: function depends on a single variable, e.g., speech signal
  - Multi-dimensional signals: function depends on two or more variables, e.g., image
- Any physical phenomenon that carries or convey information from one place to other and represents as a function of independent variables such as time, distance, etc.
- Signals are represented mathematically as a function of one or more independent variable.

Signals

- In this course signals involving a single independent variable, generally refer to as a time, t are considered.
- Although it may not represent time in specific application
- A signal is a real-valued or scalar-valued function of an independent variable t.



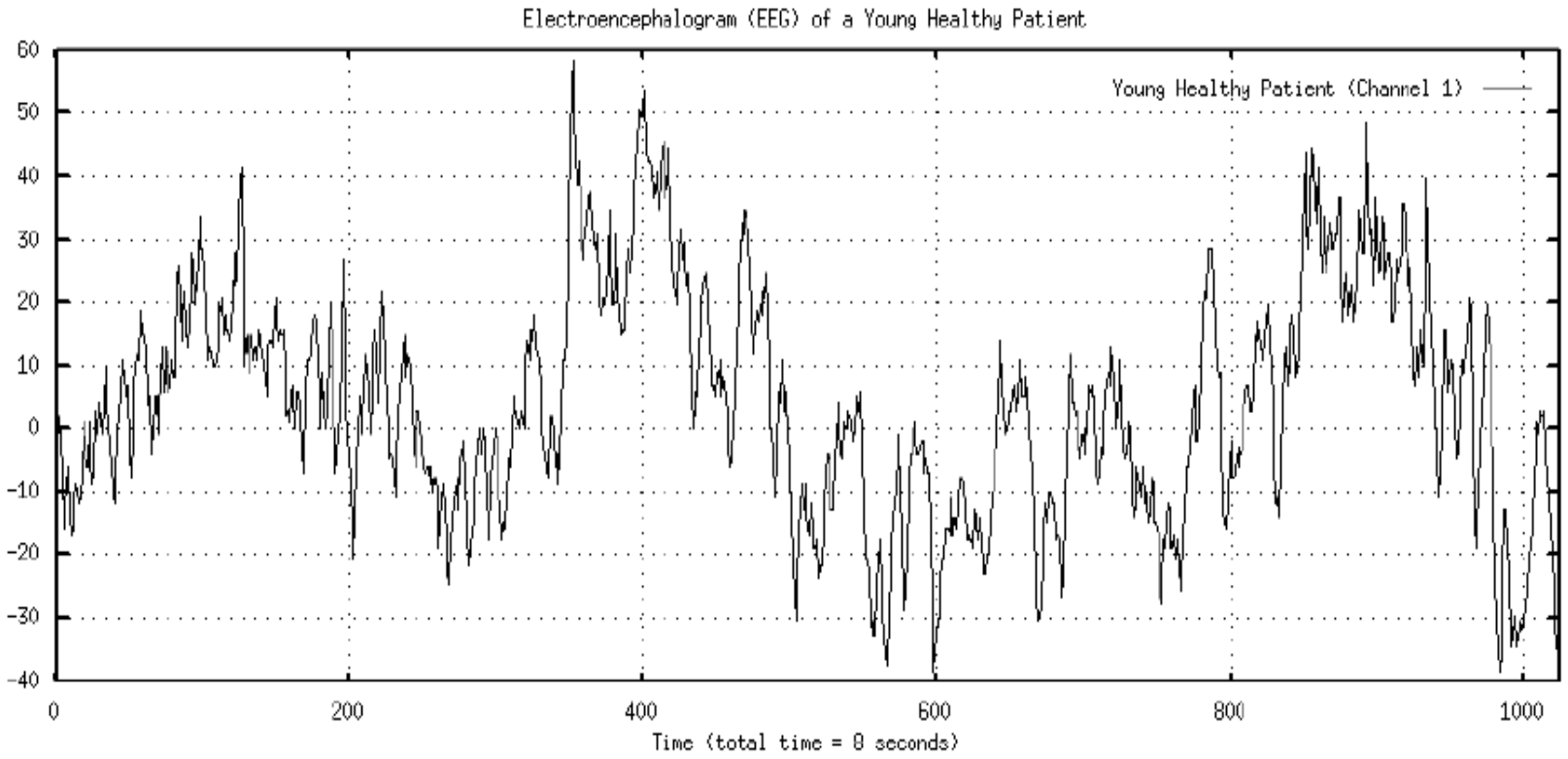
(a) Signal

Signal Examples

- Electrical signals --- voltages and currents in a circuit
- Acoustic signals --- audio or speech signals (analog or digital)
- Video signals --- intensity variations in an image (e.g. a CAT scan)
- Biological signals --- sequence of bases in a gene
- Noise: unwanted signal

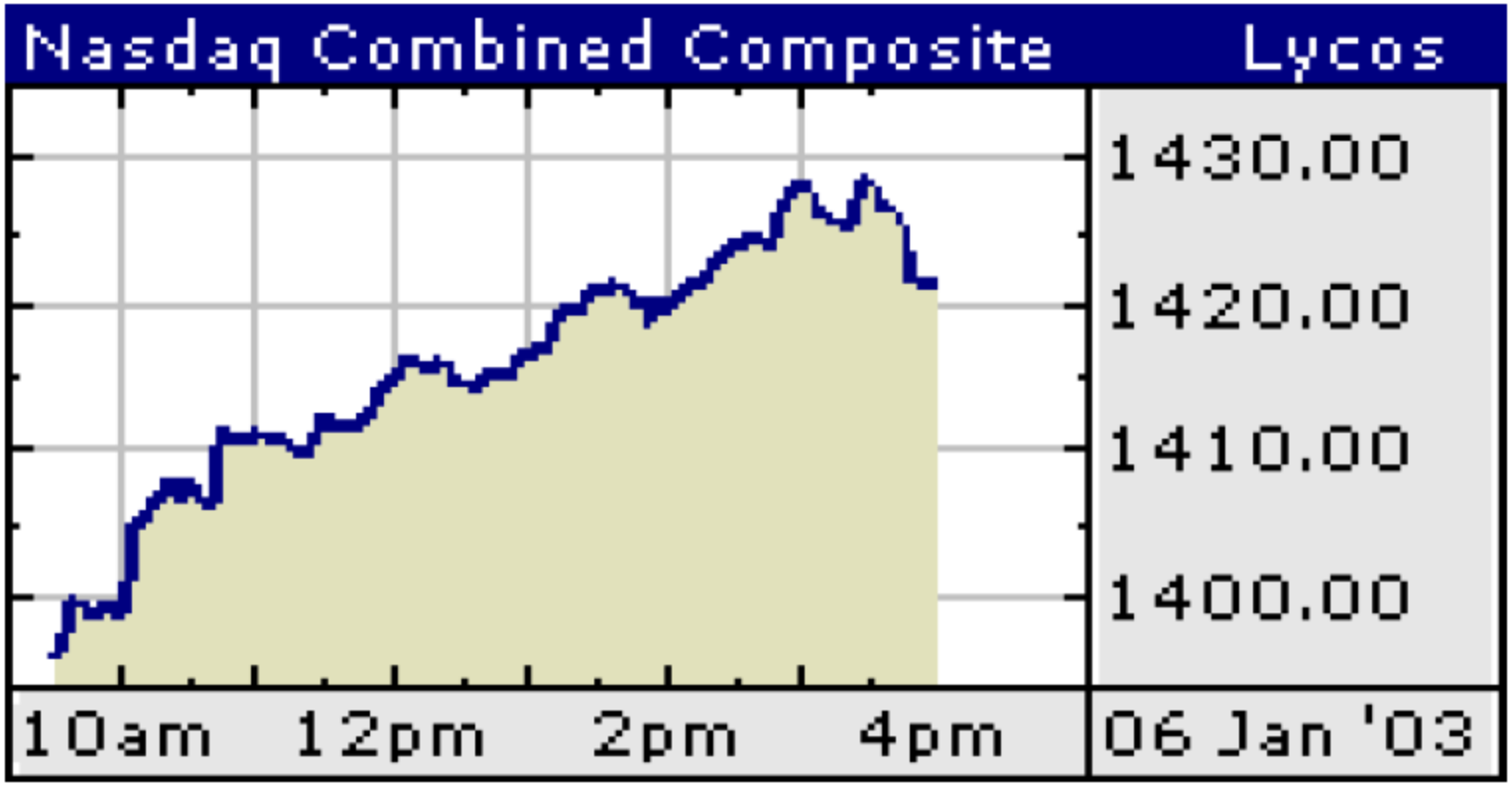
Signal Examples

Brain wave

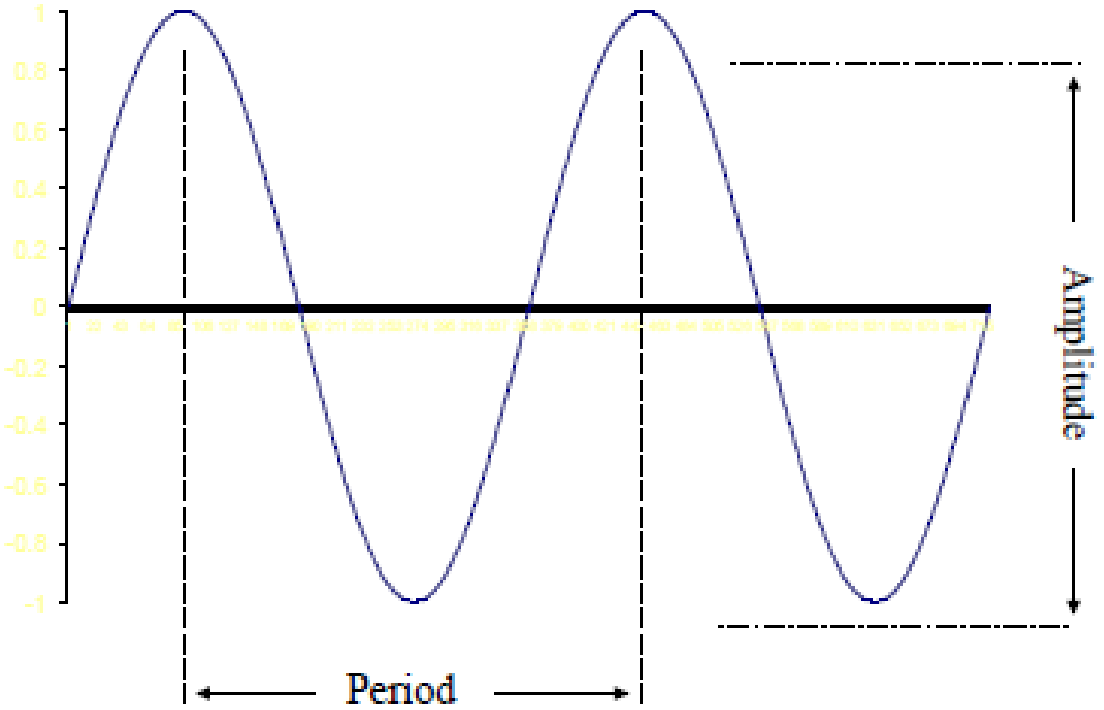


Signal Examples

Stock Market data as signal (time series)



Measuring Signals



Definitions

- **Voltage** – the force which moves an electrical current against resistance
- **Waveform** – the shape of the signal (previous slide is a sine wave) derived from its amplitude and frequency over a fixed time (other waveform is the square wave)
- **Amplitude** – the maximum value of a signal, measured from its average state
- **Frequency** (pitch) – the number of cycles produced in a second – Hertz (Hz). Relate this to the speed of a
- processor e.g. 1.4GigaHertz or 1.4 billion cycles per second

Classification of signals

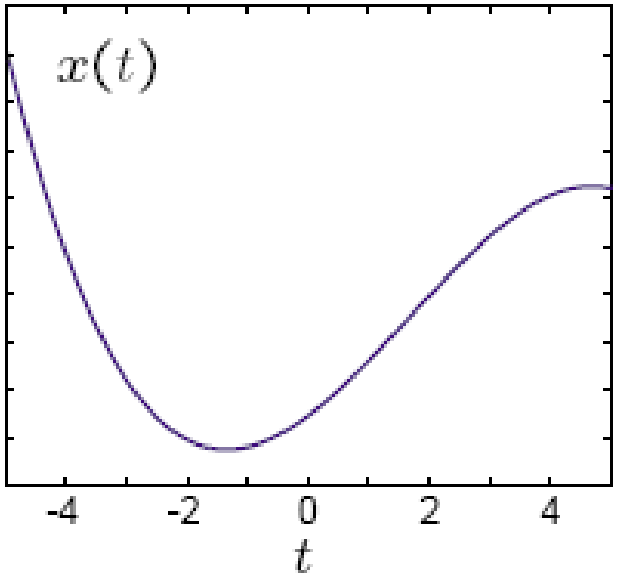
- Continuous-time and discrete-time signals
- Periodic and non-periodic signals
- Casual and Non-casual signals
- Deterministic and random signals
- Even and odd signals

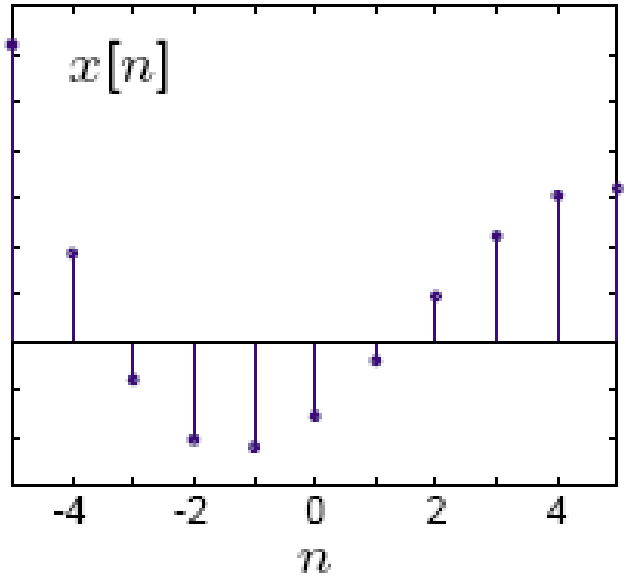
Signal Basics

Continuous time (CT) and discrete time (DT) signals

- CT signals take on real or complex values as a function of an independent.
- variable that ranges over the real numbers and are denoted as $x(t)$.
- DT signals take on real or complex values as a function of an independent.
- variable that ranges over the integers and are denoted as $x[n]$.
- Note the subtle use of parentheses and square brackets to distinguish between CT and DT signals.

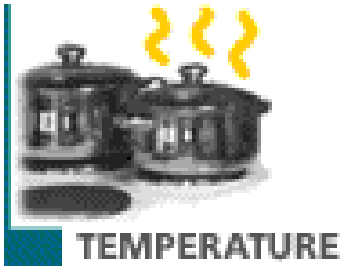
Continuous time (CT) and discrete time (DT) signals

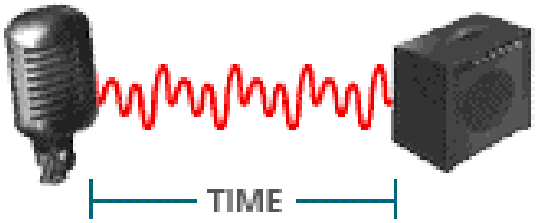


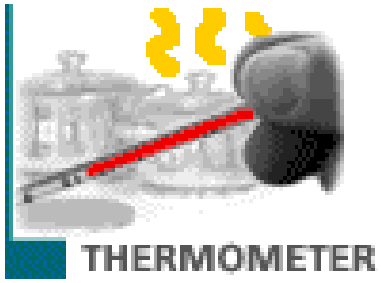


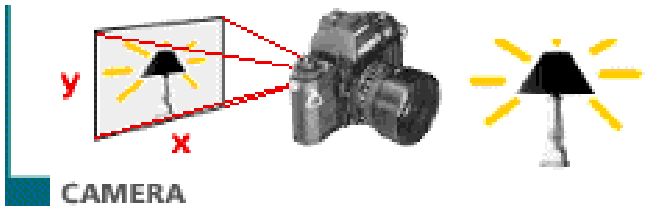
Analog Signals

- Human Voice – best example
- Ear recognizes sounds 20KHz or less
- AM Radio – 535KHz to 1605KHz
- FM Radio – 88MHz to 108MHz



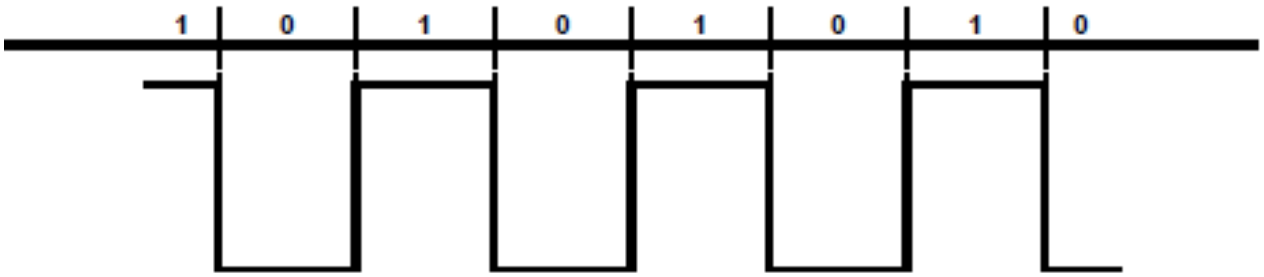






Digital signals

- Represented by Square Wave
- All data represented by binary values
- Single ***B***inary Dig***it*** – ***Bit***
- Transmission of contiguous group of bits is a bit stream
- Not all decimal values can be represented by binary



Analogue vs. Digital

Analogue Advantages

- Best suited for audio and video
- Consume less bandwidth
- Available world wide
- Less susceptible to noise

Digital Advantages

- Best for computer data
- Can be easily compressed
- Can be encrypted
- Equipment is more common and less expensive
- Can provide better clarity

Analog or Digital

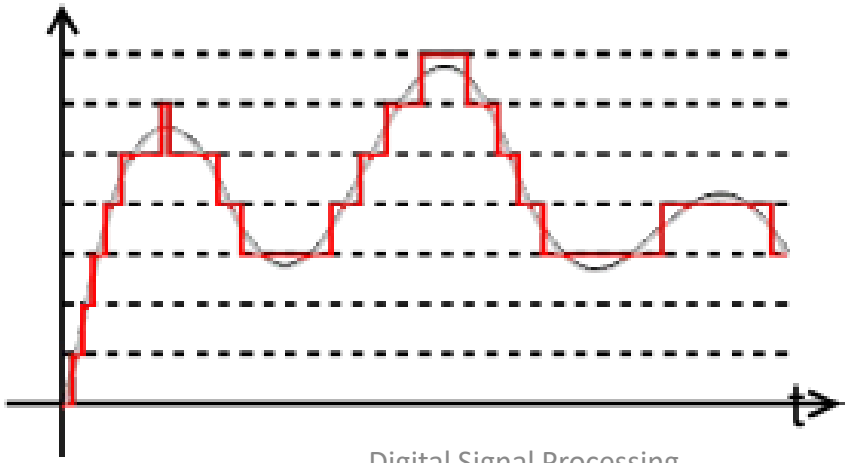
- Analog Message: continuous in amplitude and over time
  - AM, FM for voice sound
  - Traditional TV for analog video
  - First generation cellular phone (analog mode)
  - Record player
- Digital message: 0 or 1, or discrete value
  - VCD, DVD
  - 2G/3G cellular phone
  - Data on your disk
  - Your grade

A/D and D/A

- Analog to Digital conversion; Digital to Analog conversion
  - – Gateway from the communication device to the channel
- Nyquist Sampling theorem
  - – From time domain: If the highest frequency in the signal is B Hz, the signal can be reconstructed from its samples, taken at a rate not less than 2B samples per second

A/D and D/A

- Quantization
  - From amplitude domain
  - *N* bit quantization, *L* intervals *L*=2*N*
  - Usually 8 to 16 bits
  - Error Performance: Signal to noise ratio

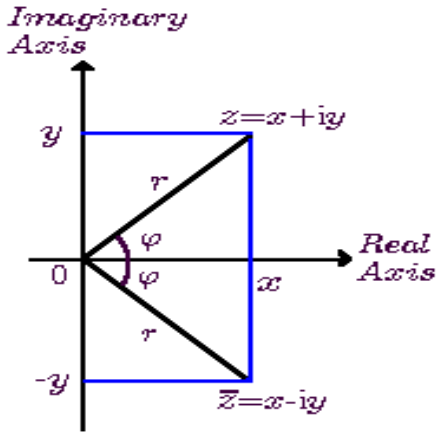


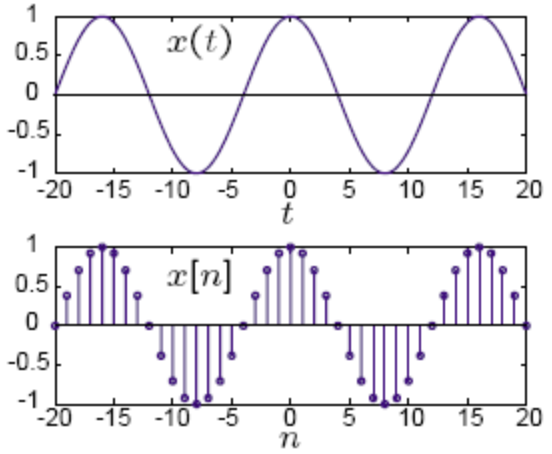
Real vs. Complex

Q. Why do we deal with complex signals?

A. They are often analytically simpler to deal with than real signals, especially in digital communications.

$$\Re\{x(t)\} = \Re\{e^{j\pi t/8}\} = \cos(\pi t/8),$$
$$\Re\{x[n]\} = \Re\{e^{j\pi n/8}\} = \cos[\pi n/8].$$





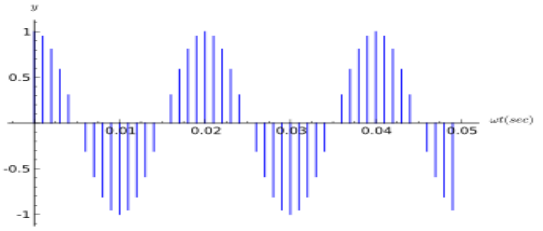
Signal processing

- SIGNAL PROCESSING is the analysis, interpretation and manipulation of like sound, images, time-varying measurement values and sensor data etc.

Types of signal processing:

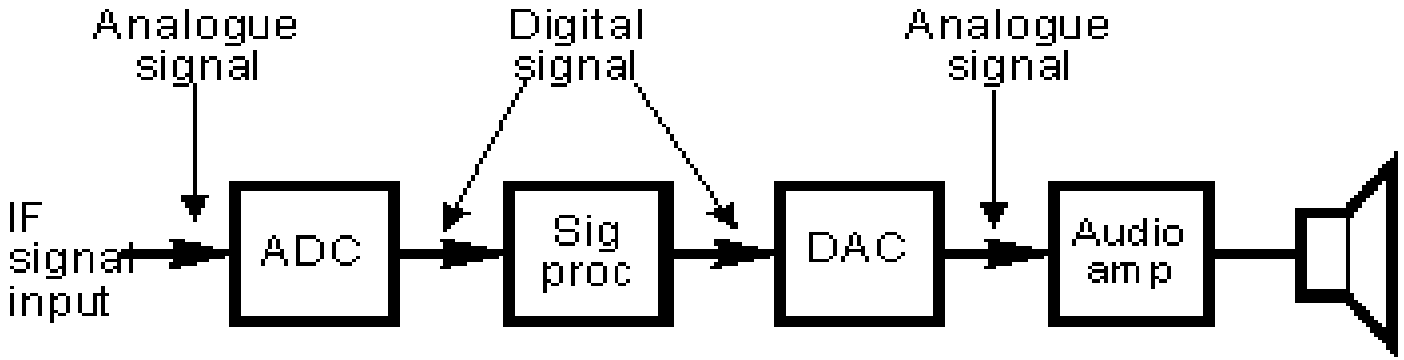
1. Analog signal processing

2. Digital signal processing

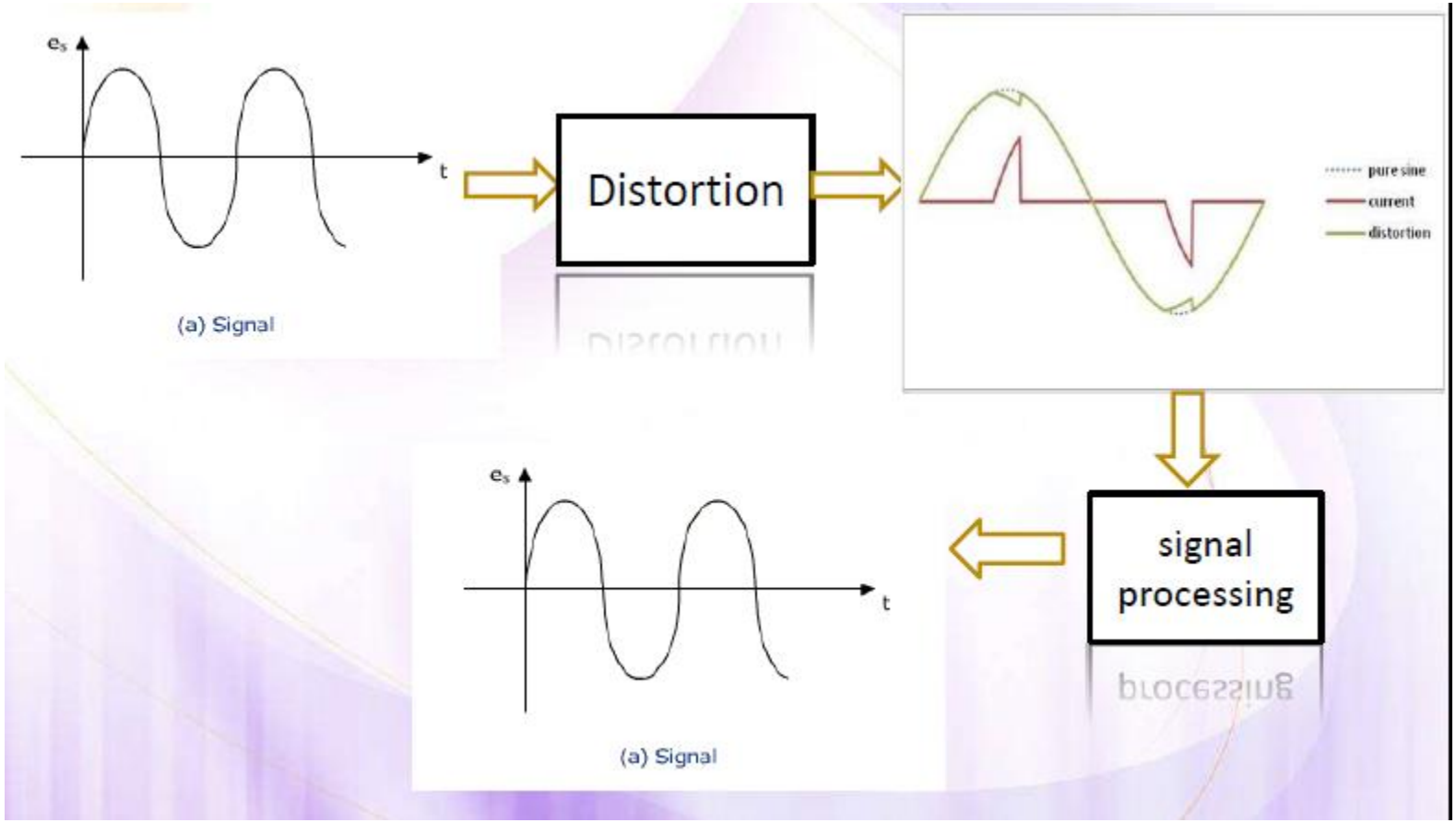


Digital Signal processing

- DIGITAL: Operating by the use of discrete signal to represent data in the form of numbers.
- SIGNAL: A parameter (electrical quantity or effect) that can be varied in such a way as to convey information.
- PROCESSING: a series operation performed according to programmed instructions.

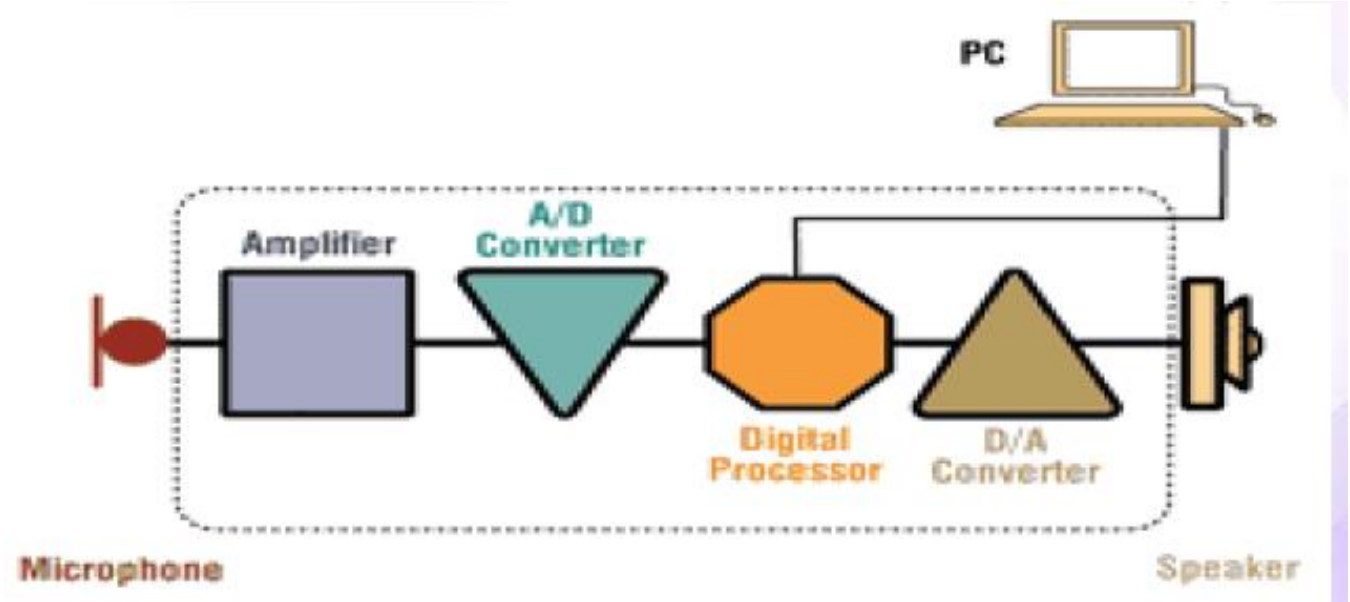


Need of Signal Processing



Principles and Operation

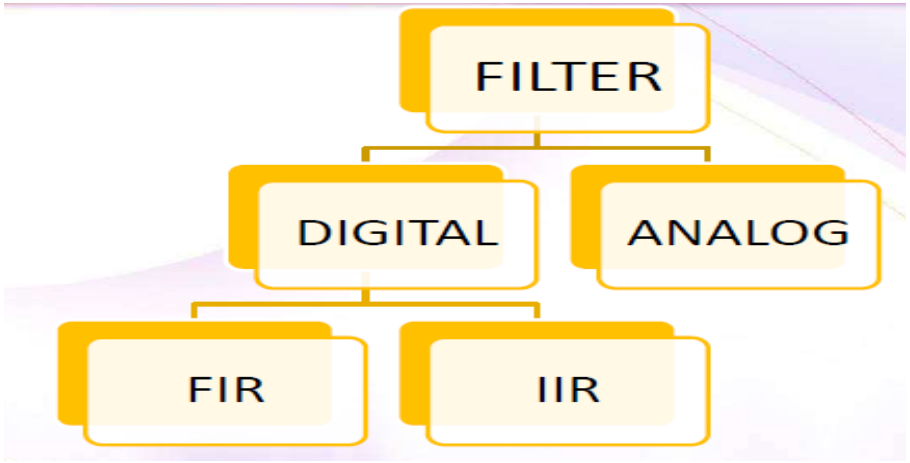
Digital signal processing consist of anti-aliasing filter ,ADC, digital processor, DAC and a reconstruction filter.



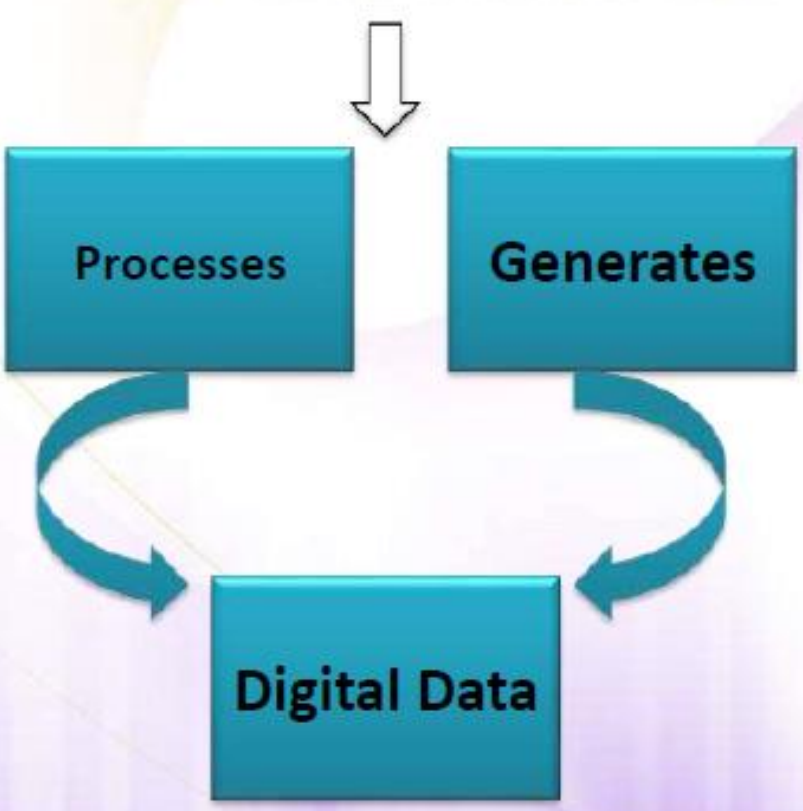
Filters

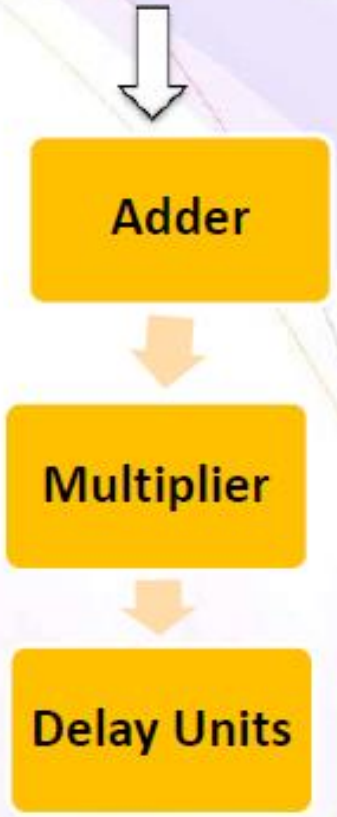
Two uses :

- Signal separation
- Signal Restoration
- Example: an audio recording made with poor equipment may
- be filtered to get the original sound.



DIGITAL FILTERS

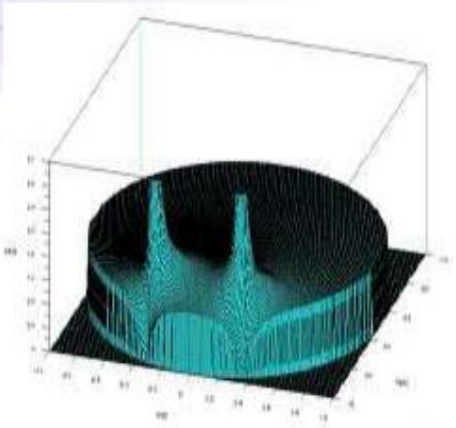




Digital filter are vastly superior in the level of performance in comparison to analog filters.

Digital Filters

- **DSP filter is immune to**:
- Environmental Changes
- Noise and relatively Stable
- Impedance Matching
- Computational Problems
- **Availability of** :
- Multiple Filtering
- Variety of Shapes for Amplitudes and Phase Response.
- Easy Transportation and Reconfiguration.



Advantages of DSP

- Accuracy
- Flexibility
- Easy operation
- Multiplexing
- Storage able

Limitations of DSP

- Antialiasing filter
- Frequency Resolution
- Quantization Error

Applications of DSP

- Image processing
- Consumer application
- Cellular mobile phones
- In Communication
- In Speech and Music
- In Biomedical
- In Radar and Sonar

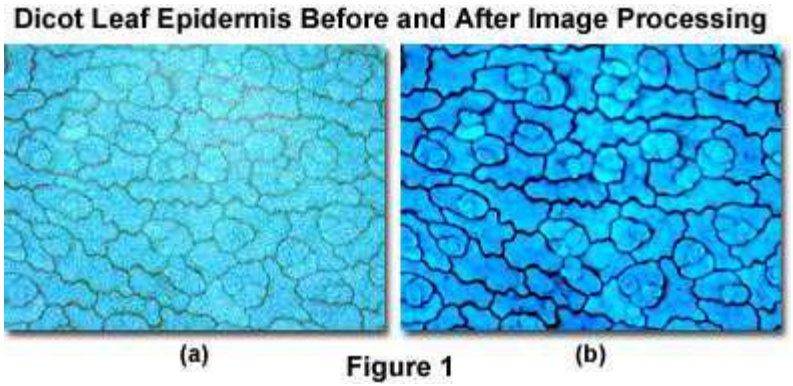


Figure 1